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Specification

1. Title of the Invention
ELECTROPHORESIS DISPLAY DEVICE

2. Claims

(1) An electrophoresis display device, comprising a liquid dispersion system including electrophoretic particles dispersed in a liquid, the liquid dispersion system being interposed between a first electrode provided on a first transparent substrate and a second electrode opposed to the first electrode, wherein a voltage is applied between the first and second electrodes so as to change a spatial distribution state of the electrophoretic particles, thus changing a reflection color of the liquid dispersion system seen through the first electrode, the electrophoresis display device being characterized in that a second transparent substrate is provided opposed to the first transparent substrate, and a transparent body having a closest possible refractive index to the refractive index of the transparent substrates is interposed between the transparent substrates.

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(2) An electrophoresis display device according to claim 1, characterized in that the transparent body is a substantially colorless liquid or resin.

(3) An electrophoresis display device according to claim 1, characterized in that the transparent body has an ultraviolet absorptivity.

(4) An electrophoresis display device according to claim 3, characterized in that the transparent body includes an ultraviolet absorptive substance, which is one of a salicylic acid derivative, a benzophenone substance or a benzotriazole substance.

(5) An electrophoresis display device according to claim 1, characterized in that the transparent body is a color filter for selectively absorbing visible light.

3. Detailed Description of the Invention

The present invention relates to an electrophoresis display device having a satisfactory contrast or a resistance against degradation due to light.

As shown in Figure 1, a conventional external mask-type electrophoresis display device includes a dispersion system 5 including white electrophoretic fine powders in a liquid which is colored black with, for example, a dye. The dispersion system 5 is interposed between a transparent electrode 2 provided on a transparent substrate 1 formed of glass or the like and an electrode 4 provided on a substrate 3 formed of an insulating material. A transparent substrate 7 having a mask layer 6 is superposed on the transparent substrate 1. A display is observed through the transparent substrate 7 by illumination light from the side of the

transparent substrate 7. When a DC voltage is applied between the electrodes 2 and 4 to cause the white particles to adhere to the electrode 2, the dispersion system 5 appears white through the transparent substrate 7. When the polarity of the applied voltage is inverted to cause the white particles to adhere to the electrode 4, the dispersion system 5 appears black through the transparent substrate 7 since the while particles are behind the black liquid. The mask layer 6 of the transparent substrate 7 is formed to be patterns such as letters and graphics by, for example, printing and forms the background of the display. A change of the reflection color of the dispersion system can be observed through areas 8 where the mask layer 6 is not provided. Accordingly, when the mask layer 6 is, for example, black and the white electrophoretic particles adhere to the electrode 2, white letters and graphics are observed on the black background. When the white electrophoretic particles adhere to the electrode 4, the entire plane becomes black and the display disappears.

However, such a conventional electrophoresis display device includes the transparent substrate 7 having the mask layer 6 which is simply superposed on the transparent substrate 1. Thus, an air layer exists between the transparent substrate 7 and the transparent substrate 1 in the areas 8 where the mask layer 6 is not provided. Accordingly, the illumination light transmitted through the transparent substrate 7 is, before reaching the dispersion system 5, inevitably partially reflected by interfaces between two layers having different refractive indices, such as a surface of the transparent substrate 7, an interface 9 between the transparent substrate 7 and the air layer, and an interface 10 between the air layer and the transparent substrate 1. The light reflected by these interfaces act to lower the

contrast of the electrophoresis display device since the light is superimposed on the light reflected by the dispersion system 5.

The intensity reflectance R at an interface between a medium having a refractive index n_1 and a medium having a refractive index n_2 is $[(n_1-n_2)/n_1+n_2)]^2$ based on the Fresnel equations, where the light is considered to be incident normally for simplicity. Even normally incident light is reflected by 4% by an interface between air (n=1) and glass ($n \fallingdotseq 1.5$). Accordingly, the above-described dispersion system, which includes a black liquid and white electrophoretic particles and is changed to be white or black by a voltage, is prevented, by the reflection by the interface, from generating a satisfactory black display when a black display is to be generated. Thus, the contrast is significantly reduced. As can be apparent from the above-described expression, the ratio of the reflection by the interface is higher as the difference between the refractive indices of two adjacent media is larger. Since the transparent substrate 7 having the mask layer 6 is provided on the transparent substrate 1, two more air-substrate interfaces are added. The conventional external mask-type electrophoresis display device having such a structure provides little color change and thus is not practical. Needless to say, other structures of electrophoresis display devices are available. For example, an internal mask-type device in which the mask layer 6 is provided on a surface of the electrode 2 in contact with the dispersion system 5 without using the transparent substrate 7, and a top mask-type device in which the mask layer 6 is provided directly on a top surface of the transparent substrate 1 without using the transparent substrate 7 are available. These devices are advantageous over the conventional device shown in Figure 1 in that the number of air-

substrate interfaces is smaller by 2. However, the former of the two devices has the mask layer 6 between the electrodes 2 and 4. Therefore, the mask layer 6 and the dispersion system 5 react with each other, or the electrode 2 is stepped by the thickness of the mask layer 6 and thus the electric field becomes non-uniform. As a result, the life of the device is likely to be shortened. The latter of the two devices, in which mask layer is directly exposed to the side on which the display is observed, allows the mask layer to be delaminated or damaged, and has a further problem of an unsatisfactory quality as the display device.

The present invention is to provide an electrophoresis display device maintaining the quality as the display device and having a satisfactory contrast without shortening the life of the device. Hereinafter, the present invention will be describe by way of an example shown in Figure 2. Elements having similar functions as those of the elements described with reference to Figure 1 bear identical reference numerals. This example is characterized in that the gap area 8 in Figure 1 is replaced with a transparent body 11 having a closest possible refractive index to the refractive index of the transparent substrate 7 or the transparent substrate 1. The refractive index of usual transparent bodies such as, for example, solvents, oils and resins is in the range of 1.3 to 1.6. In the case where glass or organic film is used for the transparent substrate 1 or 7, a transparent body having a refractive index greater than 1 is buried, so that the reflectance by the interface can be significantly lowered compared to the case where the gap is left.

In the case where a transparent body for filling the gap, such as a solvent, oil or resin is colored with, for

example, a dye so as to provide the transparent body with selective absorptivity with respect to visible light, different colors can be displayed using the same dispersion system. In other words, for example, the transparent body is colored with a yellow dye or the like, the dispersion system, which usually changes between white and blue, changes between yellow and green. In this manner, the same dispersion system can display a wider variety of colors.

An electrophoresis display device uses an organic solvent, dye, pigment or the like as the dispersion system. The composition of such a dispersion system changes by intense light radiation such sunlight, thus shortening the life of the display device. It was found by experiments that the resistance against degradation due to light of the dispersion system is improved about 3 to 7 times by cutting ultraviolet rays having a wavelength of 390 nm or shorter. Accordingly, in the case where the transparent substrate 11 provided for preventing reflection by the interface is also ultraviolet absorptive, an electrophoresis display device having a satisfactory contrast and an excellent resistance against degradation due to light can be obtained. Ultraviolet absorbents which are useful for the electrophoresis display device include the following substances.

*Salicylic acid derivatives:

phenyl salicylate, p-octylphenyl salicylate, p-tert-butylphenyl salicylate, etc.

*Benzophenones:

2-hydroxy-4-methoxybenzophenone, 2,2'-dihydroxy-4-methoxybenzophenone, 2-hydroxy-4-methoxy-2'-carboxybenzophenone, 2-hydroxy-4-n-octhoxybenzophenone, 2-hydroxy-4-

octadecyloxybenzophenone, 4-dodecyloxy-2-hydroxybenzophenone, 5-chloro-2-hydroxybenzophenone, etc.

*Benzotriazoles:

2-(2'-hydroxy-6'-methyl-phenyl)benzotriazole, 2-(2'-hydroxy-3',5'-di-tert-butyl-phenyl)benzotriazole, 2-(2'-hydroxy-4-n-octhoxy-phenyl)benzotriazole, 2-(2'-hydroxy-3,5'-di-tert-amylphenyl)benzotriazole, etc.

Among these substances, benzotriazoles are effective, and methyl-O-benzol benzoate, ethyl-2-cyano-3,3'-diphenyl acrylate and the like are also usable.

In an electrophoresis display device for simply changing the color and brightness without displaying patterns, the mask layer 6, shown in Figure 2, is unnecessary. It is sufficient that the transparent substrate 7 and the transparent substrate 1 are kept apart by a required distance and the gap is filled with the transparent body 11.

A specific example of the present invention will be described below.

For example, the following was effective as the composition of the transparent body 11 shown in Figure 2.

One hundred weight parts of Epicoat 828 (epoxy resin produced by Shell), 10 weight parts of tinuvin 328 (benzotriazole ultraviolet absorbent produced by Ciba-Geigy), and 33 weight parts of Epomate LX-1 (epoxy resin curing agent produced by Mitsubishi Petrochemical Co., Ltd.) were mixed and defoamed. Then, the resultant substance was pasted between the transparent substrates 7 and 1 while

maintaining the gap of 100 µm therebetween and cured at 60°C for 4 hours.

In order to display different colors using a single dispersion system, the above-described transparent body was colored using a dye such as, for example, Fat Yellow 3G (yellow oil-soluble dye produced by Bayer), Oil Blue 5502 (blue oil-soluble dye produced by Arimoto Kagaku) or Oil Red 5303 (red oil-soluble dye produced by Arimoto Kagaku). In this case, an electrophoresis display device in which the color changes between yellow and black, between blue and black or between red and black, respectively, was obtained using the dispersion system 5 which usually changes between white and black.

In the case where an ultraviolet absorptive liquid is used for the transparent body 11 shown in Figure 2, the transparent substrates 7 and 1 are kept apart by 100 µm, and the periphery of the assembly of the transparent substrates 7 and 1 is sealed. A hole is formed through the transparent substrate 7. For example, a 30% meta-xylene solution of UV lacquer (ultraviolet absorptive lacquer ZLI354 produced by Merck & Co. Inc.) is injected through the hole, and the hole is sealed.

The above-described transparent body has a refractive index close to that of the glass used for the transparent substrates. Therefore, the reflection by the interface between two media having different refractive indices was reduced, and thus the contrast of the displayed colors was significantly improved.

It was also found that since light rays having a wavelength of 390 µm or shorter are almost totally absorbed, the

resistance against degradation due to light is improved in some dyes about 3 to 7 times compared to the device including no transparent body.

4. Brief Description of the Drawings

Figure 1 is a cross-sectional view of a conventional external mask-type electrophoresis display device; and Figure 2 is a cross-sectional view of an external mask-type electrophoresis display device illustrating one example of the present invention.

1 ... transparent substrate; 2 ... transparent electrode; 3 ... substrate; 4 ... electrode; 5 ... dispersion system; 6 ... mask layer; 7 ... transparent substrate; 11 ... transparent body.